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Report to the Chairman, Subcommittee on Oversight and Investigations, Committee on Energy and Commerce, House of Representatives

May 2003

NUCLEAR WASTE

DRAFT

Challenges to Achieving Potential Savings in DOE's High-Level Waste Cleanup Program

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Highlights

Highlights of GAO-03-593, a report to the Chairman, Subcommittee on Oversight and Investigations, Committee on Energy and Commerce, House of Representatives

NUCLEAR WASTE

Challenges to Achieving Potential Savings in DOE's High-Level Waste Cleanup Program

Why GAO Did This Study

The Department of Energy (DOE) oversees one of the largest cleanup programs in history—the treatment and disposal of 94 million gallons of highly radioactive nuclear waste created as a result of the nation's nuclear weapons program. This waste is currently at DOE sites in Washington, Idaho, and South Carolina. In 2002, DOE began an initiative to reduce the estimated $105-billion cost of this cleanup and to reduce the length of time needed to complete the work by as much as 30 years. GAO was asked to determine the status of this initiative, the legal and technical challenges DOE faces in implementing it, and any further opportunities to reduce costs or improve program management.

What GAO Recommends

GAO's recommendations to DOE include (1) reassessing the approach for incorporating new waste separation technology at the Hanford Site; (2) seeking clarification from the Congress on DOE's authority to designate waste as other than high-level waste if a prolonged legal challenge occurs; and (3) ensuring that its waste cleanup projects are supported by rigorous analyses, adhere to best practices in incorporating new technologies, and are carefully evaluated when considering concurrent design and construction of facilities.

www.gao.gov/cgi-bin/getrpt?GAO-03-593

To view the full report, including the scope and methodology, click on the link above. For more information, contact Robin M. Nazzaro at (202) 512-3841 or nazzaror@gao.gov.

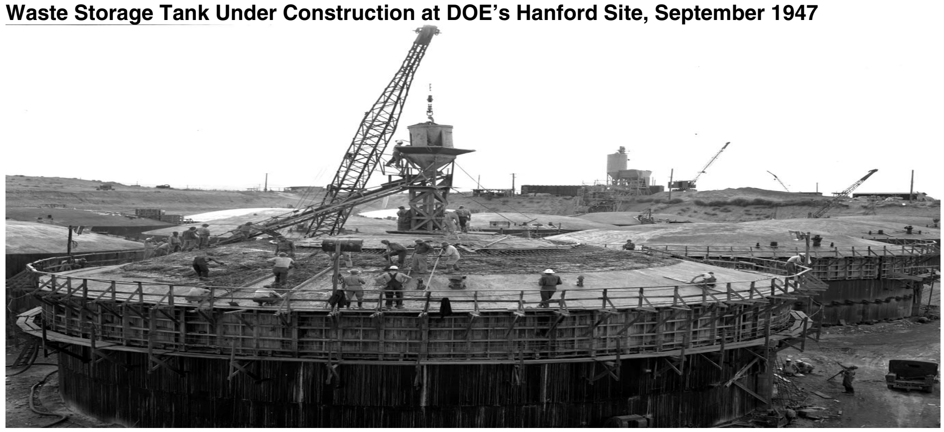
What GAO Found

DOE's initiative for reducing the costs and time required for cleanup of high-level wastes is still evolving. DOE's main strategy for treating high-level waste continues to include concentrating much of the radioactivity into a smaller volume for disposal in a geologic repository. Under the initiative, DOE sites are evaluating other approaches, such as disposing of more of the waste on site. DOE's current savings estimate for these approaches is $29 billion, but the estimate may not be reliable or complete. For example, the savings estimate does not adequately reflect uncertainties or take into account the timing of when savings will be realized.

DOE faces significant legal and technical challenges to realize these savings. A key legal challenge involves DOE's authority to decide that some waste with relatively low concentrations of radioactivity can be disposed of on site. This authority is being challenged in court, and a prolonged challenge or an adverse decision could seriously hamper DOE's ability to meet its accelerated schedules. A key technical challenge is that DOE's approach relies partly on untested methods for separating waste into high-level and low-activity portions. At the Hanford Site in Washington State, DOE is planning to implement such a method without first fully testing the technology—an approach that has failed on other projects in the past, resulting in significant cost increases and schedule delays.

DOE is exploring proposals, such as increasing the amount of high-level waste in each disposal canister, which if successful could result in billions of dollars in savings. However, considerable evaluation remains to be done. DOE also has opportunities to improve program management by fully addressing recurring weaknesses GAO has identified in DOE's management of cleanup projects.

Waste Storage Tank Under Construction at DOE's Hanford Site, September 1947



Source: DOE.

Many of the waste storage tanks, such as this one under construction at the Hanford site in 1947, were built in the 1940s to 1960s. These tanks, now underground, are used to store high-level waste, have exceeded their design life of 10-40 years, and some have leaked waste into the soil.

The Honorable James C. Greenwood
Chairman, Subcommittee on Oversight and Investigations
Committee on Energy and Commerce
House of Representatives

Dear Mr. Chairman:

The Department of Energy (DOE) oversees one of the largest cleanup programs in history: the treatment and disposal of nuclear waste created as a result of the nation's nuclear weapons program. As of 2003, one major aspect of this effort, DOE's high-level waste cleanup program, was estimated to cost nearly $105 billion and take decades to complete. High-level waste contains radioactive elements, such as plutonium and uranium, in concentrations sufficient to require long-term isolation from the environment. DOE's high-level waste results from the process of dissolving used (or "spent") nuclear fuel to remove plutonium, uranium, and other useful materials. During some of the processing, solvents and other materials can be introduced, creating waste that is both radioactive and chemically hazardous. About 94 million gallons of untreated high-level waste is stored at DOE facilities at Hanford, Washington; Savannah River, South Carolina; and near Idaho Falls, Idaho--primarily in underground tanks. This waste would fill an area the size of a football field to a depth of about 260 feet. Since the 1980s, DOE has been actively working on ways to prepare this waste for permanent disposal. These plans center on eventually placing high-level waste in an underground repository where it can be safely stored for thousands of years.

After investing more than 20 years and about $18 billion, DOE acknowledged that the program to clean up its high-level waste was far behind schedule, far over budget, and in need of major change. In February 2002, DOE began an initiative to accelerate the schedule and reduce the costs of cleaning up high-level and other radioactive and hazardous waste, while focusing its resources on reducing risks to human health and the environment at its sites. Although this initiative covers DOE’s entire cleanup program, it may have the most significant impact on DOE’s plans for high-level waste, which is the highest cost component of DOE’s cleanup program. In this context, you asked us to (1) describe the components of DOE’s high-level waste and the process involved in preparing the waste for permanent disposal, (2) discuss DOE’s initiative for accelerating its high-level waste cleanup and assess the reliability of the associated potential cost savings, (3) identify the legal and technical challenges DOE faces regarding this initiative, and (4) determine any additional opportunities to reduce the costs, as well as opportunities to improve the management of its high-level waste program.

This report is based largely on our detailed work at DOE sites where high-level waste is currently stored, and our analysis of cost information and legal documents pertaining to the high-level waste program. We obtained the assistance of a physicist with extensive experience in the nuclear field to evaluate the technical aspects of DOE’s high-level waste program. A detailed discussion of our scope and methodology is included in appendix II.

Results in Brief

DOE’s high-level waste has many types of components, ranging from radioactive isotopes and corrosive chemicals to the water in which much of this material was initially discharged. Even the radioactive components of the waste vary greatly: a small portion will remain dangerously radioactive for millions of years, while the vast majority will lose much of their radioactivity more quickly, so that more than 90 percent of the current radioactivity will be gone within 100 years. To prepare this waste for permanent disposal and meet commitments made to state and federal regulators, DOE plans to separate the waste into two waste streams, one with high levels of radioactivity and the other with lower concentrations of radioactivity. DOE expects this process will concentrate at least 90 percent of the radioactivity into a volume that is significantly smaller than the current total volume of waste. DOE plans to immobilize and bury the separated highly radioactive portion in a permanent underground repository. The remaining waste components will be immobilized—usually in a cement-like material—and disposed of at the location where it is currently stored or at some other location.

DOE's initiative to accelerate the cleanup is evolving, and its savings estimates are changing accordingly, although we have concerns about the reliability of those estimates. DOE originally estimated it could shorten the waste cleanup schedule by 20-30 years and achieve up to $34 billion in savings at its three high-level waste sites. To help achieve these schedule and cost reductions, DOE has identified alternative treatment and disposal strategies, involving such steps as developing ways to permanently dispose of more of the radioactive waste at current sites rather than moving it to the planned underground repository. As of April 2003, DOE's strategies were still being developed, and DOE had lowered the original savings estimate to $29 billion. However, our assessment of the revised estimate indicates that it may not be reliable. For example, the analysis does not take into account the cost of building some facilities required for the alternate treatment strategies. Also, the estimates of savings do not compare costs on the basis of "present value," where dollars to be saved in future years are discounted to a common year to reflect the time value of money. At Savannah River, such an adjustment would lower the site's savings estimate of $5.4 billion for accelerated waste processing to $2.8 billion (in 2003 dollars).

DOE is facing significant legal and technical challenges in implementing a number of the alternative treatment and disposal strategies. A key legal challenge linked to the strategies under consideration at all three sites involves DOE's authority to determine that some waste components with relatively low concentrations of radioactivity can be treated and permanently disposed of at the sites where the waste is currently stored. Under this authority, for example, DOE's Hanford Site has developed a treatment and disposal approach that will prepare about 90 percent of its tank waste for permanent disposal at Hanford rather than shipping it to an underground repository. DOE's authority to make such determinations is being challenged in court. A prolonged court battle could seriously hamper DOE's ability to meet accelerated schedules it has set under its new initiative. Regarding technical challenges, key elements of DOE's accelerated cleanup strategies rely on technologies for separating the waste components that have not been fully developed or tested. For example, because of schedule constraints and concerns about cost increases, the Hanford Site plans to forgo full integrated testing of its proposed process for separating wastes into high-level and low-activity portions until after facility construction is complete. This approach is not consistent with DOE's project management guidelines or the advice of several independent technical experts. On a past project to develop such facilities, failing to fully test the separation technology has resulted in significant cost increases and schedule delays. For example, at DOE's Savannah River Site in South Carolina, an attempt to speed implementation failed, after nearly $500 million had been spent on the project. DOE now plans to spend an additional $1.8 billion to develop and implement an alternative separation technology at Savannah River. We are concerned that DOE's approach at Hanford may also result in significant schedule delays and cost increases.

DOE is exploring additional potential cost savings. In addition, there are opportunities to improve program management. Additional potential cost-saving opportunities have come to light since DOE first developed its initiative, and DOE is beginning to assess these opportunities. The proposals that offer potential for significant savings are being developed by the Savannah River and Hanford sites for increasing the amount of waste that can be concentrated into the canisters destined for the permanent underground repository. DOE's data indicates that these proposals, if successful, could result in substantial savings. Considerable evaluation of these opportunities remains to be done and cost saving estimates have not yet been fully developed, according to DOE officials. DOE also has opportunities to improve its management of the cleanup program by addressing management weaknesses that we and others have identified in the past. When it began the initiative to reduce costs and accelerate the cleanup schedule, DOE acknowledged it had systemic problems with the way that the program was managed. Although DOE has taken steps to improve program management, we have continuing concerns about management weaknesses in several areas. These include making key decisions without rigorous supporting analysis, incorporating technology before it is sufficiently tested, and pursuing a "fast-track" approach of launching into facility construction before completing sufficient design work. It does not currently appear that DOE's management actions will fully address these weaknesses.

We are recommending that the Secretary of Energy reassess the approach for incorporating new waste separation technologies at the Hanford site, so that the technologies are more fully tested to ensure they will work successfully before a full-scale facility is built. We are also recommending that if the current challenge to DOE's authority becomes an extended legal process, DOE should seek clarification from the Congress on the agency's authority to determine that certain waste does not need to be treated and disposed of as high-level waste. Finally, we are making recommendations on ways to further strengthen management of the high-level waste program.

Background

High-level waste[1] contains radioactive components that emit dangerously intense radiation. Radiation is generated through a decay process in which the atoms of a radioactive component (also known as a radionuclide) lose their radioactivity by spontaneously releasing energy in the form of subatomic particles or rays similar to X-rays. Even short but extremely intense exposure to radiation can cause almost immediate health problems such as radiation sickness, burns, and in severe cases, death. Excessive exposure to these particles or rays damages cells in living tissue and is believed to cause long-term health problems such as genetic mutations and an increased risk of cancer. Because of the intense radiation emitted from high-level waste, the waste must be isolated and handled remotely behind heavy shielding such as a layer of concrete in order to protect humans and the environment. In addition to the intense radioactivity, some of the radioactive components can be very mobile in the environment and may migrate quickly to contaminate the soil and groundwater if not immobilized. Besides radioactive components, DOE high-level waste also generally contains hazardous components added during the process of dissolving used nuclear fuel to

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[1] For this report, we use the term "high-level waste" to refer to the waste that DOE is or was managing as high-level waste at its four sites.

remove plutonium and other nuclear materials. These hazardous components include solvents, acids, caustic sodas, and toxic heavy metals such as chromium and lead. Radioactive waste components, when combined with hazardous components, are referred to as "mixed wastes."

DOE has a vast complex of sites across the nation dedicated to the nuclear weapons program, but the high-level waste stemming from reprocessing spent fuel to produce weapons material such as plutonium and uranium has been limited mainly to three sites—Hanford, Washington; the Idaho National Engineering and Environmental Laboratory ("Idaho National Laboratory") near Idaho Falls, Idaho; and Savannah River, South Carolina.[2] DOE largely ceased production of plutonium and enriched uranium by 1992, but the waste remains. Most of the tanks in which it is stored have already exceeded their design life. For example, many of Hanford's and Savannah River's tanks were built in the 1940s to 1960s and were designed to last 10-40 years. (Figure 1 shows a waste storage tank being constructed at the Hanford Site.) These tanks, most of which are underground, are used to store high-level waste. Leaks from some of these tanks were first detected at Hanford in 1956 and at Savannah River in 1959. Given the age and deteriorating condition of some of the tanks, there is concern that some of them will leak additional waste into the soil, where it may migrate to the water table.[3]

[2] DOE also agreed to clean up high-level waste at another site—the West Valley Demonstration Project at West Valley, New York—where the state sponsored reprocessing of both commercial and DOE spent nuclear fuel. Treatment and preparation of this waste for disposal was completed in September 2002.

[3] DOE has reported that more than one million gallons of waste have been unintentionally released from the tanks into the soil through leaks at the Hanford site. In addition, DOE also intentionally discharged about 121 million gallons of radioactive tank waste directly into the ground from 1946 to 1966. At the Savannah River Site, one of the 51 tanks are estimated to have leaked tens of gallons into the soil.

Figure 1: Waste Storage Tank Under Construction at DOE's Hanford Site, September 1947

Source: DOE.

Treatment and disposal of high-level waste produced at DOE facilities are governed by a number of federal laws, including laws that define the roles of DOE and the Nuclear Regulatory Commission (NRC) in waste management. The Atomic Energy Act of 1954 (AEA) and the Energy Reorganization Act of 1974 established responsibility for the regulatory control of radioactive materials including DOE's high-level wastes.[4] The Energy Reorganization Act of 1974 assigned the NRC the function of licensing facilities that are authorized for long-term storage of high-level radioactive waste generated by DOE and others.[5] The Nuclear Waste Policy Act of 1982, as amended, defines high-level radioactive waste as "highly radioactive material resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing, and any solid

[4] The AEA authorized the Atomic Energy Commission (AEC) to provide for the safe storage of radioactive waste from defense-related activities. 42 U.S.C. 2121(a)(3). Later, the Energy Reorganization Act of 1974 abolished the AEC, transferring responsibilities to the Energy Research and Development Administration (ERDA)—DOE's predecessor—and the NRC. 42 U.S.C. 5814, 5841. In 1977, ERDA was abolished, and its functions were transferred to the newly established DOE, explicitly leaving the management of the government's radioactive waste in the hands of DOE. 42 U.S.C. 7151(a), 7133(a)(8).

[5] *See* 42 U.S.C. 5842.

material derived from such liquid waste that contains fission products in sufficient concentrations, and…other highly radioactive material that the [NRC]…determines…requires permanent isolation."[6] The act also established a process for developing and siting a geologic repository (a permanent deep disposal system) for the disposal of high-level waste and spent fuel. In 1985, President Reagan decided that an additional repository for defense waste was not needed, and directed DOE to use the repository being developed under the Nuclear Waste Policy Act to dispose of defense waste. Under amendments the Federal Facility Compliance Act of 1992 made to the Resource Conservation and Recovery Act of 1976 (RCRA), DOE generally must develop waste treatment plans for its sites that contain both radioactive (including high-level) and hazardous (non-radioactive) wastes.[7] These plans are approved by states that the Environmental Protection Agency (EPA) has authorized to administer RCRA, or by EPA in states that have not been so authorized.

DOE carries out its high-level waste cleanup program under the leadership of the Assistant Secretary for Environmental Management and in consultation with a variety of stakeholders. In addition to the EPA and state environmental agencies that have regulatory authority in states where the sites are located, stakeholders include county and local governmental agencies, citizen groups, advisory groups, and Native American tribes. These stakeholders advocate their views through various public involvement processes including site-specific advisory boards. Over the years, much of the cleanup activity has been implemented under compliance agreements between DOE and the regulatory agencies. These compliance agreements provide for establishing legally enforceable schedule milestones that govern the work to be done.

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[6] *See* 42 U.S.C. 2014(dd), 10101(12).

[7] *See* 42 U.S.C. 6939c(b).

DOE's High-Level Waste Is a Complex Mixture that Requires a Multi-Step Process to Prepare for Disposal

The waste in the tanks at Hanford, Savannah River, and the Idaho National Laboratory is a complex mixture of radioactive and hazardous components, and DOE's process for preparing it for disposal is designed to separate much of the radioactive material from other waste components. In the tanks, this mixture has transformed into a variety of liquid and semisolid forms. The radioactive components are of many different types; some remain dangerous for millions of years, while others lose much of their radioactivity in relatively short periods of time. Because most of the radioactive components decay relatively rapidly, over 90 percent of the current radioactivity will dissipate within 100 years. DOE plans to isolate the radioactive components and prepare the waste for disposal through the use of an extensive and sequential multi-step treatment process. To fulfill its current commitment to federal and state regulators, DOE expects this process to concentrate at least 90 percent of the radioactivity into a much smaller volume that can be permanently isolated for at least 10,000 years in a geologic repository. DOE plans to dispose of the remaining waste of relatively low radioactivity on-site near the surface of the ground, such as in vaults or canisters.

Waste Has Turned into a Variety of Forms

High-level waste generally exists in a variety of physical forms and layers inside the underground tanks, depending on the physical and chemical properties of the waste components. The waste in the tanks takes three main forms:

- Sludge: The denser, water insoluble components generally settle to the bottom of the tank to form a thick layer known as sludge, which has the consistency of peanut butter.

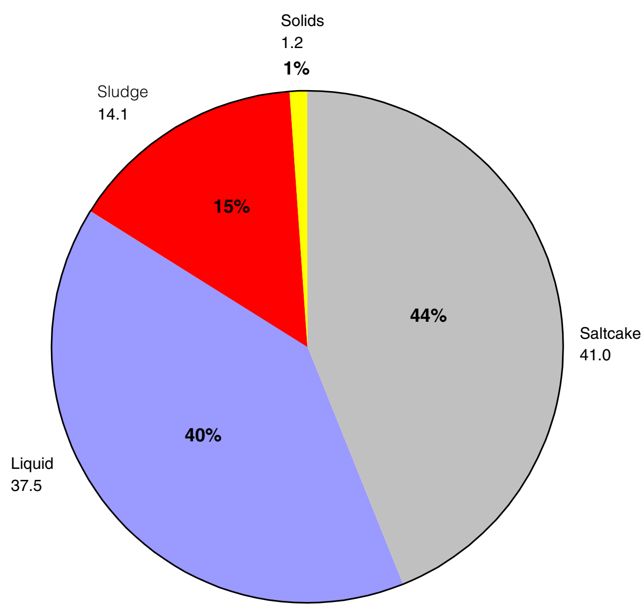
- Saltcake: Above the sludge may be water-soluble components such as sodium salts that crystallize or solidify out of the waste solution to form a moist sand-like material called saltcake.

- Liquid: Above or between the denser layers may be liquids comprised of water and dissolved salts called supernate.

As figure 2 shows, 44 percent of the total volume of high-level waste is in saltcake form, followed by liquid and sludges. In addition, a small portion of the waste volume is also in solid form and is stored in facilities other than tanks. At the Idaho National Laboratory, some waste is stored in stainless steel bins, enclosed in concrete vaults, after having undergone a thermal process that converted the liquid into a solid granular substance called calcine. At Hanford, some high-level waste was retrieved from the tanks, dried, and stored as solid material in stainless steel capsules.[8]

Figure 2: Physical Forms of DOE's Untreated High-Level Waste as a Percentage of Total Waste Volume

Gallons in Millions



Source: GAO analysis of DOE data.
Note: The values in figure 2 are for all untreated high-level waste across the DOE complex as of August 2002. At the sites, the actual distribution of the waste into the various physical forms may differ from that shown above.

The various layers of waste in the tanks are not uniformly distributed and often differ from tank to tank and even from place to place within a tank. Depending on how the

[8] From 1967 to 1985, DOE encapsulated cesium and strontium from the tank waste at the Hanford Site to reduce the amount of heat generated in the tanks and for lease to non-DOE organizations for beneficial use. All of the leased capsules have been returned to Hanford.

waste was generated and whether it was mixed or transferred from one tank to another, the layers of waste within any given tank may be unevenly distributed and liquid is interspersed between layers of saltcake. Some tanks contain all three main waste forms—sludge, saltcake and liquid—while others contain only one or two forms. Tank contents also vary among sites. For example, at the Idaho National Laboratory most tanks contain primarily liquid waste because the waste was kept in an acidic form, while at Hanford and Savannah River, most tanks contain waste in two or three physical forms.

Much of the Radioactivity Declines Relatively Quickly

The radioactive components of the high-level waste vary greatly in terms of how long they remain radioactive, with the vast majority losing their radioactivity within years or decades. Each radioactive component, or radionuclide, in high-level waste loses its radioactivity at a rate that differs for each component. This rate of decay, which cannot be changed, is measured in "half-lives"—that is, the time required for half of the unstable atoms to decay and release their radiation. The half-lives of major radionuclides in the high-level waste range from 2.6 minutes for barium-137m[9] to 24,131 years for plutonium-239. To illustrate, for any given number of radioactive barium-137m atoms, half will lose their radioactivity within 2.6 minutes. After another 2.6 minutes, half of the remaining unstable atoms will lose their radioactivity, leaving only one-fourth of the original number of unstable atoms still radioactive. The process is the same, but the half-life intervals much longer, for long-lived radionuclides, such as plutonium-239 atoms. For radioactive plutonium-239 atoms, half will lose their radioactivity within 24,131 years, and half of the remainder will lose their radioactivity after another 24,131 years.

Currently, nearly all of the radioactivity in DOE's high-level waste originates from radionuclides with half-lives of about 30 years or less. As table 1 shows, about 98 percent of the radioactivity of the high-level waste comes from four radionuclides:

[9] The "m" in barium-137m denotes barium-137 that has an excess of energy and will undergo radioactive decay to barium-137, which is not radioactive.

barium-137m, cesium-137, strontium-90, and yttrium-90. Of these, cesium-137 is the longest lived, with a half-life of 30.17 years.

Table 1: Major Short-Lived Radionuclides Contributing to the Current Radioactivity in DOE's Untreated High-Level Waste

Major short-lived radionuclides:	Half-life in years	Percent of total radioactivity in DOE's high-level waste as of August 2002
Barium-137m[a]	0.0000049[b]	25.6%
Yttrium-90[a]	0.0073[c]	22.8%
Strontium-90	28.6	22.8%
Cesium-137	30.17	27.0%
Major short-lived radionuclides total:		**98.2%**

Source: GAO analysis of DOE data.

Notes: The radionuclides listed contain the largest amount of radioactivity in curies relative to other radionuclides in DOE's untreated high-level waste. Other radionuclides, including those with longer half-lives, contain the remaining balance of the total current radioactivity.

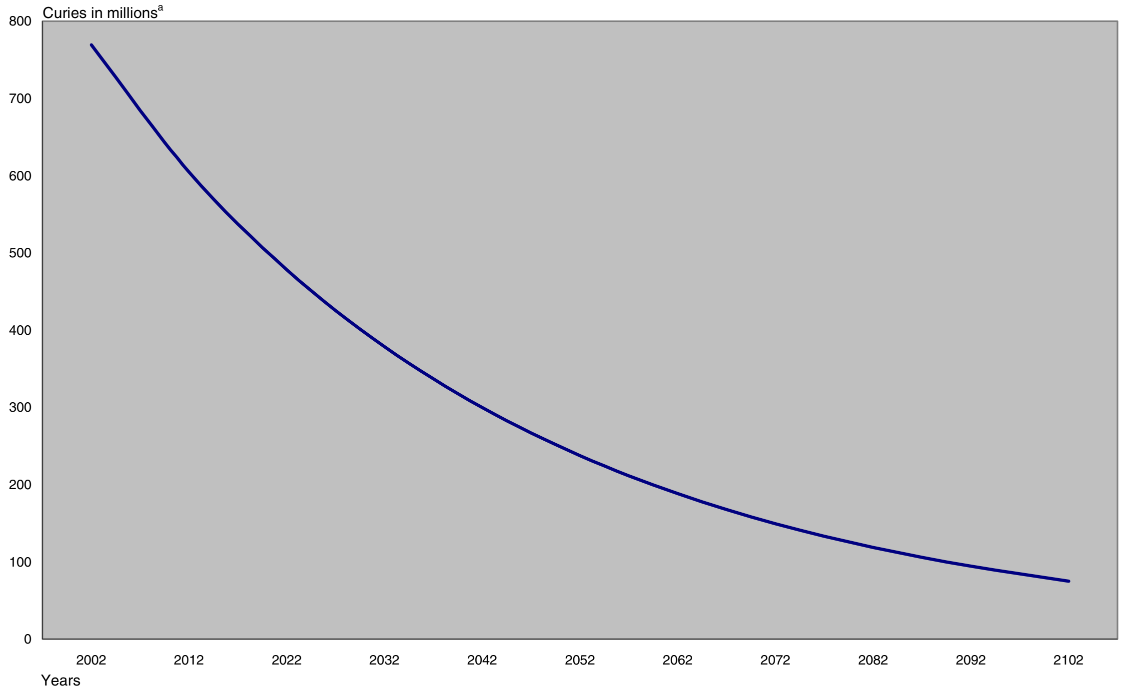
[a] Barium-137m and yttrium-90 are generated from the radioactive decay of cesium-137 and strontium-90 respectively. Consequently, as long as cesium-137 and strontium-90 are present, barium-137m and yttrium-90 will also be present.

[b] 2.6 minutes.

[c] 2.7 days.

The relatively short half-lives of most of the radionuclides in the waste means that much of the total current radioactivity will decay within 100 years. For example, within 30 years, about 50 percent of the current radioactivity in DOE's wastes will have decayed away, and within 100 years, this figure will rise to more than 90 percent. Figure 3 shows the pattern of decay, using 2002 to 2102 as the 100-year period. Extending the analysis beyond the 100-year period shown in the figure, in 300 years, 99.8 percent of the radioactivity will have decayed, leaving 0.2 percent of the current radioactivity remaining.

Figure 3: Natural Decay of Radionuclides in DOE's Untreated High-Level Waste from 2002 to 2102



Source: GAO analysis of DOE data.

Note: [a] Radioactivity is measured in a unit called a curie. One curie equals 37 billion atomic disintegrations per second.

Despite the relatively rapid decay of the current radioactivity in high-level waste, a variety of long-lived radionuclides will remain radioactive for a very long time and must be isolated from the environment. Radionuclides with half-lives greater than cesium-137 (30.17 years), such as plutonium-239 and americium-241, which have half-lives of 24,131 years and 432.2 years respectively, will continue to pose a threat to human health and the environment for thousands of years. Once the radionuclides with relatively short half-lives have decayed away, the longer-lived radionuclides will be the primary source of radioactivity in the waste. Some of these long-lived radionuclides, such as technetium-99, are potentially very mobile in the environment and therefore must remain permanently isolated. If these highly mobile radionuclides leak out or are released into the environment, they can contaminate the soil, air, and water.

Processing Can Concentrate the Radioactivity into a Much Smaller Volume of Waste

DOE's process for dealing with its high-level waste centers on separating the various components of the waste so that the portion that is most radioactive can be concentrated into a much smaller volume. While currently all high-level waste is radioactive and dangerous, significant portions of the waste, such as contaminated water, will have low levels of radioactivity if separated from most of the radionuclides that are highly radioactive. Contaminated water currently represents 54 percent of the total waste by volume across the DOE complex.[10] In overview, DOE's process generally involves separating the waste into two main streams. One, the high-level portion, will contain at least 90 percent of the radioactivity and a small portion of the waste volume. The other stream, the low-activity portion, will contain 10 percent or less of the total radioactivity but most of the waste volume.

DOE's plans for treating the waste currently call for a set of steps to be applied to the waste at each site. The primary steps are shown in table 2.

Table 2: Main Steps in DOE's Approach to Preparing High-Level Waste for Disposal

Step in process	Description
Characterization	Determination of the specific physical, chemical, and radiological components of the wastes in each tank. This step is important because some tanks contain a complex mixture of unknown waste constituents, and detailed knowledge of tank contents is needed to determine how to best retrieve, pretreat, and treat the wastes. Characterization involves analyzing samples drawn from each tank, and reviewing records of waste transfers and prior samples.
Retrieval	Removal of the stored waste from the tanks by pumping or other means and its transfer to treatment facilities. Because the waste exists in liquid, solid, and other forms, certain steps may be needed to turn the waste into a form that will allow the pumping to take place.
Pretreatment	Separation of the high-level portion of the waste from the low-activity portion and from other nonradioactive elements, such as aluminum, organic compounds, and salts. Evaporation is used during pretreatment to reduce the volume of contaminated water in the waste. This step is desirable because it decreases the amount of high-level waste that must be treated and sent to the high-level waste repository. The remaining low-activity waste can then be treated and disposed of less expensively on-site.
Treatment	Immobilization of the waste. DOE plans to vitrify the high-level portion of the waste separated during pretreatment by mixing it with a glass-forming material and melting the mixture into glass. The molten glass will be poured into stainless steel canisters to harden. The remaining low-activity portion of the waste will generally be mixed with cement and other materials so that it will harden into a cement-like substance called grout.[a]
Disposal	Final emplacement of the immobilized waste so as to ensure isolation from the surrounding environment until it is no longer dangerously radioactive. DOE plans to temporarily store the canisters containing the high-level portion of the waste on-site until an underground geologic repository is ready to receive them permanently. The remaining immobilized waste will be disposed of on-site or at other designated near surface disposal sites.

Source: GAO.

[a] At the Hanford Site, DOE currently plans to vitrify the low-activity portion of the waste.

[10] The percentage of the waste volume that is contaminated water varies between sites. Contaminated water is a significant constituent of the waste by volume because water is used to cool the waste, dilute the waste for treatment and transfer from one location to another, and flush out waste from pipelines and facilities.

DOE plans to permanently dispose of the high-level portion of the separated waste in a geologic repository developed pursuant to the Nuclear Waste Policy Act. This repository is intended to isolate highly radioactive waste materials from the public and the environment for at least 10,000 years. The remaining low-activity portion would be immobilized in accordance with federal and state environmental laws and the agreements made with state regulators and disposed of permanently on-site, or at other designated locations.

Although radionuclides with long half-lives are present in both the high-level and low-activity portions of the waste after the separations processes are concluded, the portion of the waste not sent to the geologic repository will have relatively low levels of radioactivity and long-lived radionuclides. Based on current disposal standards established by the NRC, if the radioactivity of this remaining waste is sufficiently low, it can be disposed of on-site near the surface of the ground, using less complex and expensive techniques than those required for the highly radioactive portion.

DOE has successfully applied this process in a demonstration project at the West Valley site in New York state. At West Valley, separation of the low-activity portion from the high-level portion of the waste reduced by 90 percent the quantity of waste requiring permanent isolation and disposal at a geologic repository. The high-level portion was stabilized in a glass material (vitrified) and remains stored at the site pending completion of the high-level waste geologic repository and resolution of other issues associated with disposal costs.[11] The remaining low-activity portion was mixed with cement-forming materials, poured into drums where it solidified into grout (a cement-like material), and remains stored on-site.

[11] At Savannah River, high-level sludge from the tanks has also been stabilized in glass material and is currently stored on-site pending completion of the geologic repository. As of August 30, 2002, Savannah River had produced 1,331 canisters of this stabilized waste.

DOE's Initiative for Accelerating Cleanup Is Still Evolving, with the Extent of Savings Uncertain

DOE's new initiative, implemented in 2002, attempts to address the schedule delays and increasing costs DOE has encountered in its efforts to treat and dispose of high-level waste. This initiative is still evolving. DOE originally identified several strategies to help it reduce the time needed to treat and dispose of the waste. Based on these strategies, DOE set a goal of achieving up to $34 billion in savings at its three high-level waste sites and reducing the waste cleanup schedule by about 20 to 35 years compared to the existing program baseline.[12] As of April 2003, DOE's strategies were still under development, and DOE had revised the savings estimate to $29 billion. However, even the $29 billion estimate may not be reliable. While savings are likely if the strategies are successfully implemented, the extent of the savings is still uncertain.

Initiative Centers on Ways to Speed Disposal and Save Money

For the most part, DOE's past efforts to treat and dispose of high-level waste have been plagued with false starts and failures, resulting in steadily growing estimates of the program's total cost. Since the cleanup activities began about 20 years ago, DOE has spent about $18 billion in its attempts to prepare high-level waste for disposal. However, less than 5 percent of the waste has been successfully treated to date. Uncontrolled cost overruns, numerous schedule delays, and unsuccessful attempts to develop treatment processes have pushed the overall estimated cost of the high-level waste program from about $63 billion in 1996 (when the first comprehensive estimates were developed) to nearly $105 billion in 2003.[13]

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[12] Unless otherwise noted, all dollar estimates are as reported by DOE and are in current dollars.

[13] Both of these lifecycle cost estimates reflect actual program costs incurred from fiscal year 1982 to the year of the estimates, and estimates through completion of cleanup.

In an attempt to gain control over DOE's waste management program and to better ensure its affordability, in February 2002 the Assistant Secretary for Environmental Management undertook a new initiative aimed at accelerating cleanup at DOE's sites and focusing on more rapid reduction of environmental risks. The initiative came as a result of an internal review of the cleanup program, which identified numerous problems and recommended a number of corrective actions. Among other things, the review noted that the cleanup program was not based on a comprehensive, coherent, technically supported risk prioritization, was not focused on accelerating risk reduction, and was not addressing the challenges of uncontrolled cost and schedule growth. A main focus of the initiative is high-level waste, including both the technical approach to treating the waste and improving how DOE manages the contracts and project activities.[14]

DOE developed strategies to speed the cleanup and reduce risk at all three sites. Many of these proposals involved ways to do one or more of the following:

- Dealing with some tank waste as low-level or transuranic[15] waste, rather than as high-level waste. Doing so would eliminate the need to prepare the waste for off-site disposal in the geologic repository for high-level waste. Disposing of waste in the repository currently is based on immobilizing the waste in a glass-like substance through a process called vitrification.

- Completing the waste treatment more quickly by using additional or supplemental technologies for treating some of the waste. For example, DOE's Hanford Site is considering using up to four supplemental technologies, in addition to vitrification, to process its low-activity waste. DOE believes these technologies

[14] U.S. Department of Energy, *A Review of the Environmental Management Program* (Washington, D.C.: Feb. 4, 2002).

[15] Low-level radioactive waste is defined as radioactive material that is not high-level radioactive waste, spent nuclear fuel, transuranic waste, or certain by-product material (the tailings or wastes produced by the extraction or concentration or uranium or thorium from any ore processed primarily for its source material content) 42 U.S.C. 10101(16). Transuranic wastes come primarily from reprocessing of spent nuclear fuel and from fabrication of nuclear weapons. Transuranic waste is defined as waste with radionuclides with atomic numbers greater than 92 (that is, uranium) and having half-lives greater than 20 years in concentrations greater than 100 nanocuries per gram.

are needed to help ensure it can meet a schedule milestone date of 2028 agreed to with regulators to complete waste processing. Without these technologies, DOE believes waste treatment would not be completed before 2048.

- Segregating the waste more fully than initially planned and tailoring waste treatment to each of the four segregated waste components. By doing so, DOE plans to apply less costly treatment methods to components with lower concentrations of radioactivity.

- Closing waste storage tanks earlier than expected. DOE plans to begin closing tanks earlier than scheduled, thereby avoiding the operating costs involved in maintaining the tanks and monitoring the wastes.

Table 3 shows major site-by-site proposals that have been made.

Table 3: Examples of Proposals under Study for Accelerating the High-Level Waste Treatment Process

Site	Types of proposals
Hanford (Washington State)	• Building one higher capacity vitrification facility to process the waste instead of two smaller facilities. • Developing supplemental technologies to enhance waste treatment operations at the single facility. • Using a single system to retrieve the waste from each tank rather than two systems as initially planned. • Accelerating the shipment of waste to the repository. • Closing tanks earlier.
Savannah River (South Carolina)	• Conducting more thorough waste separations than initially planned and then tailoring waste treatment separately to each waste stream. This would allow Savannah River to do the following: o Apply less costly treatments than initially planned to the low-activity waste streams. For example, DOE will remove waste with the lowest concentrations of radioactivity and treat it directly by grouting it, rather than first processing it through a more costly pretreatment facility. o Adjust vitrification of high-level sludges to each individual batch of waste processed. By doing so, DOE expects to place about 25 percent more waste in each canister, reducing the overall number of canisters that will need to be produced and stored at the repository. • Closing tanks 8 years earlier than scheduled.
Idaho National Laboratory (Idaho)	• Repackaging calcined waste and shipping it directly for disposal at the geological repository, rather than vitrifying it. • Classifying the remaining liquid tank wastes as transuranic wastes, which would require less costly treatment than previously planned before being shipped off site to a transuranic repository.

Source: Developed by GAO from DOE information.

DOE's initial estimates in August 2002 were that, if the proposals were successfully implemented, total savings could be about $34 billion compared to the baseline cost estimate in place when the accelerated initiative began. As of April 2003, the savings estimate associated with the new strategies had been revised to about $29 billion (see table 4). DOE officials told us many of their new strategies are still under development, and that savings estimates are still subject to additional revision.

Table 4: DOE's Estimated Cost Savings from Proposals to Accelerate Cleanup of High-Level Waste

Amounts are in billions of current dollars, fiscal 2003 to end of cleanup

Site	Current baseline lifecycle cost estimate	Accelerated lifecycle cost estimate	Estimated savings from accelerated initiatives
Idaho National Laboratory	$10.07	$ 3.10	$ 6.97
Hanford	56.19	41.67	14.52
Savannah River	18.82	11.49	7.33
Totals	**$85.08**	**$56.26**	**$28.82**

Source: DOE.

Note: West Valley is not included in this table because high-level waste cleanup at the site was essentially completed in Sept. 2002.

Current Savings Estimates May Not Be Reliable

Our review of these savings estimates suggests that they may not yet be reliable and that the actual amounts to be saved if DOE successfully implements the strategies may be substantially different from what DOE is projecting. We have several concerns about the reliability and completeness of the savings estimates. These concerns include the accuracy of baseline cost estimates from which savings are calculated, whether all appropriate costs are included in the analysis, and whether the savings estimates properly reflect uncertainties or the timing of the savings.

Baseline Costs Are Not Fully Reliable

DOE's current lifecycle cost baseline is used as the base cost from which potential savings associated with any improvements are measured. However, in recent years, we and others have raised concerns about the reliability of DOE's baseline cost estimates. In a 1999 report, we noted that DOE lacked a standard methodology for sites to use in developing their lifecycle cost baselines, raising a concern about the reliability of data used to develop these cost estimates.[16] DOE's Office of Inspector General also raised a concern in a 1999 review of DOE project estimates, noting that several project cost estimates examined were not supported or complete. DOE itself acknowledged in its February 2002 review of the cleanup program that baseline cost estimates do not provide a reliable picture of project costs.[17]

The National Research Council, which has conducted research on DOE's project management, has reported on why DOE's baseline cost estimates are often unreliable. It noted in 1999 that DOE often sets project baselines too early, and that industry practice calls for completing from 30 to 35 percent of design before establishing a baseline cost estimate.[18] In a recent example, we found that the estimated contract price of Hanford's high-level waste treatment facility is expected to increase to $5.8 billion, about $1.6 billion above the original $4.2 billion contract price established in December 2000. The original cost estimate was established when less than 15 percent of the facility design was complete. The cost increase, in large part, is due to failing to keep the design work ahead of construction activities, adding funds for unforeseen occurrences, and making some facility modifications not in the original contract.

Accelerated Cost Estimates May Be Incomplete

A second reason for concern about the cost savings estimates is that some of the savings may be based on incomplete estimates of the costs for the accelerated proposals.

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[16] U.S. General Accounting Office, *Nuclear Waste: DOE's Accelerated Cleanup Strategy Has Benefits but Faces Uncertainties*, GAO/RCED-99-129 (Washington, D.C.: Apr. 30, 1999).

[17] U.S. Department of Energy, *A Review of the Environmental Management Program* (Washington, D.C.: Feb. 4, 2002).

[18] National Research Council, *Improving Project Management in the Department of Energy* (Washington, D.C.: June 1999).

According to OMB guidance on developing cost estimates, agencies should ensure that all appropriate costs are addressed in the estimate. However, for example, the Idaho National Laboratory estimates savings of up to $7 billion, in large part, by eliminating the need to build a vitrification facility to process waste currently in calcine form and in tanks, as well as achieving associated reductions in operations and decommissioning costs. The waste, as is, may have to undergo an alternative treatment method before it can be accepted at a geological repository. The Idaho National Laboratory plans to use one of four different technologies currently being evaluated to treat its tank waste. DOE's savings estimate reflects the potential cost of only one of those technologies. DOE has not yet developed the costs of using any of the other waste treatment approaches. DOE noted that the accelerated lifecycle estimate could likely change as one of the technologies is selected and associated costs of treating the waste is developed.

Savings Estimates Do Not Reflect Timing, Uncertainty or Non-Budgetary Impacts

A third area of concern is that DOE's savings estimates generally do not accurately reflect the timing of when savings will occur, the uncertainty associated with cost estimates or the reliability of a technology, or the value of potential non-budgetary impacts of the alternative strategies. According to OMB guidance, agencies should ensure that the timing of when the savings will occur is accounted for, that uncertainties are recognized and quantified where possible, and that non-budgetary impacts, such as a change in the level of risk to workers, are quantified, or at least described. Regarding the time value of money, applying OMB guidance would mean that estimates of savings in DOE's accelerated plans should reflect a comparison of its baseline cost estimate with the alternative, expressed in a "present value," where the dollars are discounted to a common year to reflect the time value of money. Instead, DOE's savings estimates generally measure savings by comparing dollars in different years. For example, the Savannah River Site estimates a savings of nearly $5.4 billion by reducing by 8 years (from 2027 to 2019) the time required to process its high-level waste. Adjusting the savings estimate to present value in 2003 results in a savings of $2.8 billion in 2003 dollars.

Regarding uncertainties, in contrast to OMB guidance, the DOE savings estimates generally do not consider uncertainties. For example, the savings projected in the Idaho National Laboratory's accelerated plan reflect the proposal to no longer build the vitrification facility and an associated reduction in operations costs. However, the savings do not account for uncertainties, such as whether alternatives to vitrification will succeed and at what cost. Rather than reflecting uncertainties by providing a range of savings, DOE's savings estimate is a single point estimate of $7 billion.

Regarding non-budgetary impacts, DOE's savings estimates generally did not fully assess the value of potential non-budgetary impacts, such as a change in the level of risk to workers or potential effects on the environment. OMB guidelines recommend identification, and where possible, quantification of other expected benefits and costs to society when evaluating alternative plans. An example where non-budgetary impacts were partially, but not fully, considered is the Idaho National Laboratory. The Idaho National Laboratory's accelerated plan notes that its proposal not to vitrify its calcined high-level waste significantly reduces risk to workers and the environment by eliminating the exposure that would have been incurred in cleaning up and decommissioning the vitrification facility once waste treatment had been completed. While site officials told us such analyses are currently underway, the impact has not yet been reflected in the savings estimate. However, the proposal does not assess potential increases in environmental risk, if any, from disposing of the waste without stabilizing it into a vitrified form. By not assessing these benefits and risks to workers and the environment, DOE leaves unclear how important these risks and trade-offs are to choosing an alternative treatment approach.

Key Legal and Technical Challenges Could Limit Potential Savings from DOE's Accelerated Cleanup Initiative

DOE faces significant legal and technical challenges to achieving the cost and schedule reductions proposed in its new initiative. On the legal side, DOE's proposals depend heavily on the agency's authority to apply a designation other than "high-level waste" to the low-activity portion of the waste stream, so that this low-activity portion does not have to be disposed of as high-level waste. DOE's authority to make such determinations is being challenged in court. On the technical side, DOE's proposals rest heavily on the successful application of waste separation methods that are still under development and will not be fully tested before being put in place. DOE's track record in this regard has not been strong; it has had to abandon past projects that were also based on promising—but not fully tested—technologies. Either or both of these challenges could limit the potential savings from DOE's accelerated cleanup initiative.

DOE's Initiative Relies Heavily on Authority That Is Being Challenged in Court

DOE is involved in a lawsuit over whether it has the authority to manage some tank wastes containing lower concentrations of radioactivity as other than high-level waste. The outcome could affect DOE's ability to move forward with waste treatment on an accelerated schedule. If DOE retains its ability to manage much of the waste as other than high-level waste, it can apply less expensive treatment methods to that portion of the waste, dispose of the waste on-site, and close the tanks more quickly. If DOE loses the legal challenge, these faster and less expensive treatment alternatives may not be available. Regardless of the outcome, if an extended legal process ensues, DOE may be prevented from realizing the full potential savings associated with its accelerated cleanup initiative.

DOE's Authority and Procedures for Designating Waste as "Incidental"

DOE has traditionally managed all of the wastes in its tanks as high-level waste because the waste resulted primarily from the reprocessing of spent nuclear fuel and contains significant amounts of radioactivity. However, DOE based its approach to treatment and disposal on the radioactivity and actual constituents in the waste, as well as the source of the waste. Focusing on the radioactivity and constituents would allow DOE to use less costly and less complicated treatment approaches for the majority of what is now managed as high-level waste.

DOE has developed a process for deciding when waste in the tanks should not be considered high-level waste. In July1999, DOE issued Order 435.1 setting forth procedures for the management of its radioactive wastes. Under this Order, DOE formalized its process for determining which waste is incidental to reprocessing ("incidental waste"), not high level waste, and therefore will not be sent to a geological repository for high-level waste disposal. This process provides a basis for DOE to treat and dispose of some portion of its wastes less expensively as low-level or transuranic wastes.

DOE's Order 435.1 establishes the specific criteria for defining the waste that could be considered incidental to reprocessing and therefore is not high-level waste and would not require the vitrification treatment that high-level waste must undergo for disposal purposes. The criteria were developed in conjunction with the NRC, the governmental entity with regulatory authority over disposal facilities for high-level waste. The criteria generally are that the waste (1) has been or will be processed to remove key radioactive components to the maximum extent technically and economically practical; (2) will be disposed of in conformance with the safety requirements for low-activity waste as laid out in NRC regulations; and (3) will be put in a solid physical form and will not exceed radioactivity levels set by the NRC for the most radioactive category of low-level waste, referred to as "Class C standard."[19] DOE must first satisfy itself internally that these requirements have been met for waste it wants to determine is waste incidental to reprocessing and therefore not high-level waste. DOE then obtains a technical review of

[19] As required by NRC regulations (10 C.F.R. 61.55), Class C low-level waste must not only meet the most rigorous requirements for low-level waste form to ensure stability, but also requires additional measures at the disposal site to protect against inadvertent intrusion. The criteria also allow DOE to authorize and use alternative requirements for radioactive concentration limits.

its determination from the NRC, which provides a concurrence that DOE has met its criteria.[20] DOE then considers the waste not to be high-level waste, but waste that can be managed as either low-level or transuranic waste.

Designation as "Incidental" Would Apply to Much of the Waste

DOE's ability to define some waste as incidental to reprocessing, and to then follow a different set of treatment and disposal requirements for that waste, is central to its overall strategy for addressing its tank waste. For example, DOE plans to use its incidental waste process to manage about 90 percent of its 54 million gallons of tank waste at Hanford as low-level waste, rather than process it through a high-level waste vitrification facility. Using that approach, most of the waste would be eligible for treatment and disposal on-site. Such an approach would be less expensive than treating all of the waste as high-level waste and sending it for disposal in a high-level waste geologic repository. DOE has no current estimate of the cost increase if all 94 million gallons of tank wastes had to be treated in a high-level waste vitrification facility and stored at a geological repository. However, a 1996 environmental impact statement at the Hanford Site estimated such an alternative for the Hanford Site alone would add about $29 billion-$37 billion (in 1995 dollars), nearly doubling project costs at that site alone, primarily due to increased disposal costs at the repository. Furthermore, there would probably not be enough space at the high-level waste repository to dispose of all of this waste.

Hanford is not the only site affected; as of April 2003, DOE had developed incidental waste determinations for waste at all four of its high-level waste sites.[21] In all, DOE had used its authority to designate some of its tank waste as low-level or transuranic waste in

[20] Although DOE is not required to gain NRC's concurrence with its incidental waste determinations, it does so to obtain an independent assessment of its evaluation of waste as incidental to reprocessing.

[21] Because West Valley separated out and treated its waste before the waste incidental to reprocessing criteria was formalized in Order 435.1 in 1999, DOE followed criteria established in the NRC requirements for low-level waste (10 C.F.R. 61.55). We did not include this action in table 5.

seven separate incidental waste determinations (see table 5). DOE is planning to initiate further incidental waste determinations as it removes the waste from additional tanks.

Table 5: Description and Status of DOE Incidental Waste Determinations for Tank Waste

Site	Waste included in incidental waste determination	Incidental waste to be managed as	Estimated volume of incidental waste	Status
Hanford	Those tank wastes to be separated from high-activity wastes through using separations processes.	Low-level waste.	Approximately 90 percent of Hanford's 54 million gallon waste inventory.	DOE approved this determination prior to issuing its Order 435.1, although DOE essentially followed the same criteria found in 435.1. The NRC agreed but said that if DOE decides to treat some of its low-activity waste with technologies other than vitrification, as it plans under its accelerated initiative, DOE may need to update its determination.
Savannah River	Residual tank waste left in tanks 17 and 20 at closure.	Low-level waste.	Approximately 3500 gallons of residual waste left in the two tanks.	DOE approved this determination prior to issuing its Order 435.1, although DOE essentially followed the same criteria found in 435.1.
Savannah River	Saltwaste to be treated through the grout (Saltstone) facility.	Low-level waste.	Up to 12.3 million gallons of tank waste.	DOE approved the determination, but has not implemented it pending resolution of a lawsuit and other issues.
Savannah River	Residual tank waste left in tank 19 at closure.	Low-level waste.	12,000 to 13,000 gallons of solids in tank 19 at closure.	Awaiting DOE approval.
Idaho National Laboratory	Sodium bearing waste in tanks.	Transuranic waste (to be disposed of at an off-site transuranic repository).	900,000 gallons of acidic liquid in tanks.	Awaiting DOE approval.
Idaho National Laboratory	Residual waste left in tanks at closure.	Low-level waste.	Actual amount of residuals left in the tank will be determined at time of individual tank closure.	Awaiting NRC and DOE approval.
West Valley	Sodium bearing waste in tanks.	Low-level waste.	12,000 gallons	DOE has approved.

Source: DOE officials.

Note: DOE has incidental waste determinations that apply to other than tank waste, such as equipment and materials used in managing high-level waste, such as contaminated transfer pumps and job wastes. We did not include those determinations in this table.

Legal Challenges to DOE's Authority to Manage Its Tank Waste

DOE is currently involved in a lawsuit focused on its authority to make incidental waste determinations. In March 2002, the Natural Resources Defense Council, Inc. and others filed a lawsuit challenging DOE's authority to manage its wastes through its incidental waste process.[22] A primary concern of the plaintiffs is that DOE will use its incidental waste process to permanently leave intensely radioactive waste sediments in the tanks with only minimal treatment. The lawsuit alleges that DOE's incidental waste process improperly allows DOE to reclassify high-level waste as incidental waste that does not need to be treated in the same way as high-level waste. According to the plaintiffs, the Nuclear Waste Policy Act defines all waste originating from a given source—that is, from reprocessing of spent nuclear fuel—as high-level waste and requires that such waste be managed as high-level waste, yet DOE has chosen to differentiate its wastes according to the level of radioactivity and manage them accordingly.

This is not the first legal action that resulted from DOE's process for determining which part of its waste can be designated as incidental to reprocessing and will not be managed as high-level waste. For example, in 1993, the NRC denied a formal petition from the states of Washington and Oregon requesting that NRC establish the process and criteria for determining what part of DOE's radioactive waste could be managed as other than high-level waste.[23] The states' request stemmed from concerns that the criteria DOE was applying to wastes had not been formally established by regulation and thus had not been given public scrutiny. The NRC, in its ruling, concluded that DOE's process for determining what waste was incidental to reprocessing was appropriate for making individual tank-by-tank incidental waste determinations, and that the NRC had no jurisdiction. Later, in 1998, the National Resources Defense Council petitioned the NRC

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[22] *Natural Resources Defense Council. v. Abraham*, No. 01-CV-413 (D. Idaho, filed Mar. 5, 2002). The lawsuit was originally filed in January 2000 in the 9th Circuit Court of Appeals, and was subsequently transferred to the federal district court in Idaho. The other parties to the lawsuit are The Snake River Alliance, the Confederated Tribes and Bands of the Yakama Nation and the Shoshone Bannock Tribes. In addition, the states of Washington, Idaho, Oregon and South Carolina are participating as *amicus curiae.*

[23] *See* 58 Fed. Reg. 12,342 (1993).

to assume immediate licensing authority over the 51 tanks at the Savannah River Site, arguing that DOE invented the term "incidental waste" as a means of circumventing NRC's authority and oversight and, furthermore, that waste to be left in the bottom of the tanks at Savannah River did not meet DOE's own definition of incidental waste. The NRC concluded it did not have regulatory authority over high-level or residual wastes at Savannah River.[24]

Uncertainty about DOE's Authority Could Delay Implementing New Initiatives

The current legal challenge, as well as any future challenges, could affect DOE's efforts to implement its accelerated treatment and disposal strategies. For example, the challenge could place on hold indefinitely all pending incidental waste determinations. Since the start of the lawsuit, DOE has not implemented any incidental waste determinations and has not yet decided whether to defer or move forward with its pending incidental waste determinations—such as for closing tanks. DOE is concerned that moving forward to implement such determinations could create a risk that the court could place a general ban on making any decisions about the waste until the legal challenge is resolved. In addition, final resolution of the challenge could be further delayed if either party appeals the decision.

A lengthy legal process could result in delays in moving forward with treatment plans for this waste, and delays in closing tanks on an accelerated schedule. For example, the Idaho National Laboratory plans to begin closing tanks in the spring of 2003, but approval for the incidental waste determination to close the tanks by managing tank waste residuals as low-level waste is still pending.[25] A DOE official at the Idaho National Laboratory told us that while a delay of several months in obtaining incidental waste approval would not present an immediate threat to schedule dates, a delay beyond 24 months would seriously impact the site's ability to meet its accelerated 2012 date to

[24] *See* 65 Fed. Reg. 62,342 (1998).

[25] Tank closure at the Idaho National Laboratory is also pending completion of its NEPA process.

close all of the tanks. Savannah River also plans to begin closing additional tanks starting in early 2004.[26] A DOE official at the Savannah River site said that if the lawsuit continues, the site may miss a legally binding date agreed to with regulators to begin closing the tanks.

If the court invalidated DOE's incidental waste determination process, DOE may need to find an alternative solution for treating and managing its wastes that would allow it to treat waste with lower concentrations of radioactivity less expensively. In that case, DOE could begin experiencing delays affecting progress at all three of the high-level waste sites that rely on incidental waste determinations. For example, as one of its savings strategies, DOE plans to manage about 12.3 million gallons of its waste at Savannah River as low-level waste and treat it through a grout facility. DOE estimates it could begin treating this waste as early as August 2003. Although DOE has approved an incidental waste determination for this waste, the grout treatment facility must receive an operating permit from state regulators. To date, the state has withheld approval for the permit, pending resolution of the lawsuit. A site official said without the permit, DOE cannot go forward with its plans to accelerate treatment of the waste.

At this point, the Department does not appear to have a strategy in place to avoid the potential effects of challenges to its incidental waste determination authority, either from the current lawsuit or future challenges. In a December 2002 internal memorandum, the Assistant Secretary for Environmental Management issued guidelines for proceeding with making incidental waste determinations as necessary to meet cleanup commitments and requirements. However, these guidelines only include ensuring that such determinations meet the legal requirements of Order 435.1; the guidelines do not include any alternative strategies for dealing with the waste. DOE officials told us that they believe the department will prevail in the legal challenge. Because the outcome of the lawsuit is so uncertain, DOE believes it would be premature to explore alternative strategies to overcome potentially significant delays to the

[26] The Savannah River Site closed its first tanks—tanks 17 and 20—in 1997.

program that could result from a protracted legal conflict or from an adverse decision. As of April 2003, DOE had just begun to look at potential delays that could result from a lengthy legal challenge, but had developed no formal strategy to deal with those delays. Such strategies could range from exploring alternative approaches for establishing an incidental waste regulation to asking that the Congress clarify its intentions regarding DOE's authority to implement an incidental waste policy.

Initiative Also Relies Heavily on Waste Separation Approaches That Will Not Be Fully Tested

DOE's initiative also faces key technical challenges related to the process for separating the various components of the waste. Waste separation involves a sequential process of filtering and extracting each major high-level waste constituent, such as cesium-137 and strontium-90, from the waste. DOE guidance recognizes the risks involved in implementing a technology without first thoroughly testing it. In order to save time, however, DOE managers at the Hanford Site are planning some of their strategies around waste separation technologies that will not be fully tested before being implemented. Past projects that took this approach have experienced major problems, and outside reviewers have raised cautions about DOE's plans to use the same approach in this instance.

Separating Waste Is Key to Treating It Economically

Separating high-level waste into its various components is central to DOE's treatment and disposal plans. Since the late 1980's, federal and state agreements have reflected DOE's plan that the waste be processed so that at least 90 percent of the radioactivity in high-level waste is concentrated into a much smaller waste stream and prepared for permanent isolation in a geological repository. The low-activity waste portion, which represents the majority of the waste volume but significantly less radioactivity, must also be immobilized according to federal and state agreements.

Separating the waste components is important not only to meet legal agreements, but also to meet waste cleanup schedule and cost goals. If the waste is not separated, all of it—about 94 million gallons—would have to be treated as high-level waste and disposed of in the geological repository. Doing so would require a much larger repository than currently planned, and drive up disposal costs by billions of dollars. Successful separation will substantially reduce the volume of waste needing disposal at the repository, as well as the time and cost required to prepare it for disposal, and allow less expensive methods to be used in treating and disposing of the remaining low-activity waste.

The waste separation process is complicated, difficult, and unique in scope and size at each site. The waste differs among sites not only in volume but also in the way it has been generated, managed, and stored over the years.[27] Although the main steps in the process may vary, waste separation generally involves a sequential process of filtering and extracting various high-level waste constituents from the tank waste (see figure 4 below). The waste treatment approach at the Hanford Site involves designing, building, and operating one-of-a-kind separations processes and facilities. Developing successful waste separations process has proved challenging for DOE in the past, especially at Savannah River, and the current plans for Hanford are no less challenging.

[27] Progress in successfully separating the waste also varies at each site. Waste separation operations at the West Valley site were completed in 1995. As part of its accelerated cleanup plan, the Idaho National Laboratory is evaluating its need for separation technologies for its liquid tank wastes. The subsequent discussion focuses on separation processes at the Hanford and Savannah River sites.

Figure 4: Simplified Description of Key Steps in Hanford's Proposed Process for Separating High-Level Waste Constituents

Retrieve Waste	To prepare waste for the separations process, DOE will retrieve the waste, evaporate excess water, and make it available for separations processing.
Remove Strontium	Strontium-90[a] and other constituents, such as plutonium and americium, are separated as solid waste particles through a chemical process and/or filtration and directed to the high-level waste stream.
Remove Solids	The remaining waste flows through an extensive filtering and recycling process to separate out solid high-level waste particles. These particles flow to the high-level waste stream and the remaining liquid that includes dissolved cesium-137 flows to the next separations step.
Remove Cesium	Cesium-137[a] is removed through a process called ion exchange. Concentrated solution with cesium flows to the high-level waste stream, and the remaining solution flows to the low-activity waste stream.[b]
Treat Separated Waste	Radioactive waste from the high-level waste stream is vitrified and poured into steel canisters, about 15 feet tall and 2 feet wide. Waste from the low-activity waste stream is vitrified and placed in steel containers, about 8 feet tall and 4 feet wide.[c]
Dispose of Waste	High-level waste canisters will be stored temporarily on-site until they can be shipped to a geologic repository. Low-activity waste containers will remain permanently on-site in near-surface disposal facilities.

Source: DOE.

[a] Yttrium-90 and barium-137m, which are generated from strontium-90 and cesium-137 respectively, are also present in the waste but additional steps to separate these constituents are not necessary because after separation from their related constituents (strontium-90 and cesium-137), they will decay within a few weeks until they are no longer radioactive.

[b] DOE's original plan was to remove technetium-99 at the same time as cesium-137. However, DOE officials at the Hanford Site now plan to leave technetium-99 in the low-activity waste stream rather than separating and diverting it to the high-level waste stream where it would be vitrified.

[c] Both the high-level and low-activity waste streams contain various components of hazardous waste. Some hazardous components will be destroyed during the vitrification process. DOE plans to apply to the Environmental Protection Agency to have the remaining hazardous components declared safe for long-term storage and disposal. If successful, the components will remain in the immobilized waste.

Hanford Plans to Build Facilities to Separate Waste Before Fully Testing the Separation Processes to Be Used

At its Hanford site, DOE intends to build a facility for separating the waste before fully testing the separation processes that will be used. The technology for separating waste components at Hanford is being developed at several laboratories, including Savannah River's Technology Center. These facilities are performing tests to help validate underlying assumptions about how the processes will work. The laboratory testing includes a combination of "scale up" and pilot-scale testing of individual processes and use of operational data for certain separation processes, but integrated testing will not be completed until full-scale facilities are constructed. DOE plans to fully test the processes for the first time during the operational tests of the newly constructed facilities.

This approach does not fully reflect DOE guidance for incorporating new or complex technology into a project, which calls for ensuring that the technology is mature before integrating it into a project. More specifically, DOE's project management order 413.3 requires DOE to assess the risks associated with technology at various phases of a project's development. For projects with significant technical uncertainties that could affect its cost and schedule, corrective action plans are required to determine how the uncertainties will be resolved before the project can proceed. In addition to this order, DOE has drafted supplementary project management guidance. This guidance suggests that technologies are to be developed to a reasonable level of maturity before a project can progress to full implementation to reduce risks and avoid cost increases and schedule delays. The guidance suggests that DOE avoid the risk of performing concurrent facility design and technology development.

The laboratories working to develop Hanford's waste separation process have identified several technical uncertainties, which they are working to address. These uncertainties or critical technology risks, include problems with separating waste solids through an elaborate filtration system, problems associated with mixing the waste during separation processes, and various problems associated with the low-activity waste evaporator. The contractor is also concerned about the availability and performance of a special resin for separating out cesium 137, a radioactive constituent. The resin is currently produced by only one supplier, and that supplier currently does not have the manufacturing capability to produce the resin in the quantities needed for DOE's full-scale operations, according to contractor officials. In an effort to resolve this uncertainty, DOE's construction contractor has asked the manufacturer to expand resin production capability and in April 2003, DOE signed a contract modification that allows alternative resins to be used in the separation process.

Given these and other uncertainties, Hanford's construction contractor and outside experts have seen Hanford's approach as having high technical risk and have recommended further testing before construction.

- In April 2002, concerned about the potential of operational problems of the waste separation processes, Hanford's construction contractor proposed building an integrated testing facility to confirm that Hanford's processes will work at a significantly larger scale than has been tested to date. The contractor proposed conducting fully integrated tests in a pilot facility using simulated waste before full-scale separations facilities are constructed. The contractor estimated the cost of the pilot facility at between $6 million and $12 million.

- In October 2002, an independent peer review group of industry experts concluded that an integrated pilot plant for interim testing to confirm the technical processes was a preferred approach. Several other independent experts we interviewed also shared this view. These experts are associated with the National Research Council and various research organizations, universities, and private institutions. These experts emphasized that performing integrated testing to verify that separation processes will work is an essential step, especially for the complicated waste treatment facilities that Hanford is building.

In contrast to these views, DOE's Office of River Protection has decided not to construct an integrated pilot facility and instead to accept a higher-risk approach. DOE officials said they wanted to avoid increasing project costs and schedule delays, which they believe will result from building a testing facility. Instead, Hanford officials said that they will fully test and demonstrate the separation process during facility startup operations after the full-scale treatment facilities are constructed. However, fully testing Hanford's separation process may be a bigger challenge than originally envisioned. In April 2003, DOE modified the construction contract for the waste treatment facilities and adopted a schedule compressing the facility testing and startup period from 4 years to about 2.5 years. To meet this compressed schedule and in response to DOE's decision not to construct an integrated pilot plant, Hanford's construction contractor decided in late April 2003 to drop its proposal for the pilot plant. Instead, the contractor plans to continue laboratory testing of separation processes in an effort to simulate the results of an integrated pilot plant. While contractor officials stated that their original proposal for an integrated pilot plant was technically sound, they withdrew the proposal in order to ensure that they could meet revised contract schedule and budget commitments.

Past Experience at Savannah River Shows Consequences of Deviating From Technology Development Guidelines

The consequences of not adhering to sound technology development guidelines can be severe. At the Savannah River Site, for example, DOE invested nearly $500 million over nearly 15 years to develop a waste separations process, called in-tank precipitation, to treat Savannah River's high-level waste. While laboratory tests of this process were viewed as successful, DOE did not conduct integrated testing of the components until it started full-scale operations in the newly constructed facility. At that time, major operational problems occurred. Full-scale operations resulted in production of benzene, a dangerously flammable byproduct. Operations were stopped after DOE spent about $500 million because experts could not explain how or why benzene was being produced and could not determine how to economically reconfigure the facility to minimize it. Consequences of this technology failure included significant cost increases, schedule delays, a full-scale facility that did not work, and a less-than-optimum waste treatment operation without a viable separation process. Savannah River is now taking steps to develop and implement a new separation technology at an additional cost of about $1.8 billion and a delay of about 7 years.[28]

Subsequent assessments of the problems that developed at Savannah River found that DOE (1) relied on laboratory-scale tests to demonstrate separation processes, (2) believed that technical problems could be resolved later during facility construction and startup, and (3) decided to scale up the technology from lab tests to full-scale without the benefit of using additional testing facilities to confirm that processes would work at a larger scale. Officials at Hanford are following this same approach. Several experts with whom we talked cautioned that if separation processes at Hanford do not work as planned, facilities will have to be retrofitted, and potential cost increases and schedule delays can be much greater than those associated with integrated process testing in a pilot facility.

Opportunities Exist to Explore Additional Cost Savings and to Strengthen Program Management

In addition to the potential cost savings identified in the accelerated site cleanup plans, DOE continues to develop and evaluate additional proposals to reduce costs, but is still in the process of fully assessing these proposals. Because DOE is still evaluating these proposals, the potential cost savings have not been fully developed, but could be in the range of several billion dollars, if successfully implemented. At the Savannah River and Hanford sites, for example, DOE is identifying ways to increase the amount of waste that can be placed in its high-level waste canisters to reduce treatment and disposal costs. DOE also has a number of initiatives under way to improve overall program management. However, we are concerned that they may not be adequate. In our examinations of problems that have plagued DOE's project management over the years, three contributing factors often emerged—making key project decisions without

[28] U.S. General Accounting Office, *Nuclear Waste: Process to Remove Radioactive Waste From Savannah River Tanks Fails to Work*, GAO/RCED-99-69 (Washington, D.C.: April 30, 1999).

rigorous analysis, incorporating new technology before it has received sufficient testing, and using a "fast-track" approach (concurrent design and construction) on complex projects. Ensuring that these weaknesses are addressed as part of its program management initiatives would further improve the management of the program and increase the chances for success.

DOE Is Considering Additional Potential Opportunities to Reduce Costs

DOE is continuing to identify other proposals for reducing costs under its accelerated cleanup initiative. Senior Environmental Management officials realize that the proposals to accelerate cleanup identified in site performance management plans do not represent a complete set of options for full achievement of DOE's savings goals. To pursue additional potential opportunities, the Assistant Secretary for Environmental Management commissioned several special project teams to evaluate additional program improvements and cost savings opportunities. One of these teams, the high-level waste project team, has completed the initial phase of its work. According to DOE's high-level waste project team leader, it may be some time before their proposals are fully assessed and decisions are made about how best to proceed. The Assistant Secretary will consider the proposals from the project teams, but has not stated when final decisions will occur.

Among the proposals that DOE is considering, the ones that appear to offer significant cost savings opportunities would increase the amount of waste placed in each disposal canister. We discussed these cost savings opportunities with both Savannah River and Hanford officials during our review. DOE officials at those sites have identified these potential savings opportunities as deserving further consideration, but have not yet fully assessed the potential benefits.

Opportunities at Savannah River Look Promising but Have Not Been Fully Demonstrated

Savannah River officials are working to reduce costs by increasing the amount of waste in each disposal canister. They have proposed increasing the amount of waste in each canister by developing different blends of glass material, called frit, that they believe can be tailored to each batch of waste. The amount of waste that can be placed into a canister depends on a complex set of factors, including the specific mix of radioactive material combined with other chemicals in the waste, such as chromium and sulfate, that affect the processing and quality of the immobilized product. These factors affect the percentage of waste than can be placed in each canister because they indicate the likelihood that radioactive constituents could leach out of the immobilizing glass medium and into the environment. The greater the potential for leaching, the lower the allowable percentage of waste and the higher the percentage of glass frit that must be used. DOE determines the leaching rates of the glass using a combination of chemical analysis and predictive modeling.

Based on a recent improvement made to DOE's predictive model involving adjustments to the required temperature of the melted waste, and changes to the type of glass frit used, Savannah River officials believe they can increase the amount of waste loaded in each canister from 28 percent to about 35 percent, and for at least one waste batch, to nearly 50 percent. Savannah River plans to implement this new process and begin increasing the amount of waste in each canister in June 2003. If successful, Savannah River's improved approach could reduce the number of canisters needed by about 1,000 canisters and save about $2.7 billion, based on preliminary estimates.

Beyond the specific improvements Savannah River officials have already identified, there may be an additional way to increase the loading of waste into disposal canisters, resulting in additional savings for DOE. During our review, we determined that DOE's Offices of Environmental Management and Civilian Radioactive Waste Management (Radioactive Waste Management) have different methods for evaluating the rate at which waste could leach out of the glass in the disposal canisters. By conforming to the less restrictive Radioactive Waste Management method, Environmental Management could increase the amount of waste in the canisters to a higher level.[29] After examining this possibility, Environmental Management officials at Savannah River said that, if the higher waste loading could be achieved, this change could eliminate the need for up to 650 canisters. This may permit further cost savings of about $1.7 billion. The Savannah River officials stated that they were continuing to examine this cost savings possibility.

Because Opportunities at Hanford Are in Early Development, Savings Are Not Yet Known

The Hanford Site has also proposed strategies to decrease the number of high-level waste canisters that it will need, but its approach is in the very early stage of development. In November 2002, Hanford proposed broadening the high-level waste acceptance criteria to allow waste forms other than standard borosilicate glass—the type of glass being used at Savannah River and initially planned for Hanford—to be accepted for immobilizing high-level waste. Hanford's proposal is based on recent changes to NRC's disposal requirements that will allow for waste forms other than standard borosilicate glass to be sent to the repository.[30] These changes may allow Hanford to package its high-level waste in fewer canisters.

Although it is unclear whether DOE orders will be changed to allow these other waste forms, DOE has significant incentives to do so. Reducing the number of canisters at

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[29] DOE's standard for leaching establishes a limitation on the rate at which the glass containing the waste can leach material into the environment. Radioactive Waste Management, the DOE office responsible for managing the final disposal of the waste at the geologic repository, requires that the "mean" or average of leaching rates measured or predicted for the immobilizing glass must be less than the average of leaching rates for standard glass. (This means that more than 50% of the glass produced will have a leaching rate less than the rate for standard glass.) In contrast, Environmental Management suggests (and the sites have adopted) that the average of leaching rates measured or predicted for the glass must be "at least two standard deviations below" the average leaching rates for standard glass. (This means that at least 95% of the glass produced will have a leaching rate less than the rate for standard glass.) Environmental Management's more stringent method to limit leaching can, under some circumstances, restrict the amount of waste that can be placed in the canisters more than Radioactive Waste Management's standard.

[30] In a November 2002 internal memo to Radioactive Waste Management, the Assistant Secretary for Environmental Management stated the need to revise its waste acceptance criteria to be consistent with NRC's disposal requirements. DOE has recently begun to evaluate the steps necessary to make this revision.

Hanford is especially important because, based on the expected production capacity of the high-level waste vitrification plant, only a maximum of 9,600 of the projected 12,800 canisters that DOE will need can be filled with waste by the 2028 scheduled completion date. However, by using other types of glass, Hanford estimates that it may be able to reduce its need for disposal canisters by 2,500 to 3,900 canisters.[31] If such a significant reduction in the number of canisters produced is possible, it could shorten Hanford's high-level waste treatment schedule by 6 years, save billions of dollars, and help to meet its scheduled completion date. However, the wide range of Hanford's estimate reflects the rough nature of its proposal and that cost savings have not yet been fully estimated.

DOE Has Opportunities to Improve Management of the Program by Addressing Previously Identified Weaknesses

In addition to DOE's efforts to identify site-specific proposals for saving time and money, DOE is also undertaking management improvements using teams to study individual issues. Nine teams are currently in place, while other teams to address issues such as using breakthrough business processes in waste cleanup and improving the environmental review process to better support decision making have not yet been formed. Each team has a disciplined management process to follow,[32] and even after the teams' work is completed, any implementation will take time. These efforts are in the early stages, and therefore it is unclear if they will be effective in correcting the causes of the performance problems DOE and others have identified.

We are concerned, however, that these management reforms may not go far enough in addressing performance problems with the high-level waste program. Our concerns stem from our review of initiatives underway in the management teams, our discussions with DOE officials, and our past and current work, as well as work by others inside and

[31] Based on "engineering staff judgment," depending on the waste form used, a reduction of as many as 500 canisters may be attributable to changing Environmental Management's 95 percent waste quality standard to conform to Radioactive Waste Management's 50 percent standard.

[32] Under DOE's project management principles, for example, teams must define project requirements, conduct preliminary risk assessments, and prepare a risk mitigation plan prior to developing a baseline cost estimate of proposed alternatives.

outside DOE. We have identified three recurring weaknesses in DOE's management of cleanup projects that we believe need to be addressed as part of this overall review. These weaknesses cut across the various issues that the teams are working on and are often found at the center of problems that have been identified. Two of the three weaknesses have been discussed earlier in this report, as we have identified these as potentially significant obstacles to achieving savings – lack of rigor in the analysis supporting key decisions, and incorporating technology into projects before it is sufficiently mature. The final area of weakness involves using "fast-track" methods to begin construction of complex facilities before sufficient planning and design has taken place.

Key Decisions Not Always Supported by Rigorous Current Analysis

DOE's project management guidance emphasizes the importance of rigorous and current analysis to support decision-making during the development of DOE projects. All DOE projects with costs greater than $5 million require risk management activities, including a thorough analysis, to be applied continuously, adjusting these analyses throughout the process as necessary to ensure DOE is pursuing the best value alternative at the lowest cost. Similarly, the Office of Management and Budget guidance states that agencies validate earlier planning decisions with updated information before finalizing decisions to construct facilities. This validation is particularly important where early cost comparisons are susceptible to uncertainties and change.

However, DOE does not always follow this guidance. Proceeding without rigorous review has been a recurring cause of many of the problems we have identified in past DOE projects. For example, regarding the need to validate planning decisions with updated information before finalizing decisions, the decision at Hanford to construct a vitrification plant to treat Hanford's low-activity waste has not undergone such a validation. Hanford's analysis justifying the cost of this approach was prepared in 1999 and was based on technical performance data, disposal assumptions, and cost data developed in the early 1990s—conditions that are no longer applicable. For example, the

1999 analysis compared DOE's low-activity vitrification approach with a disposal approach developed in the early 1990s that involved large underground grout vaults with elaborate environmental controls. Although this grout approach was abandoned in 1994, DOE still used these disposal assumptions for the 1999 comparison and analysis. Since that time other conditions have changed, including the performance capabilities of alternative technologies such as grout, the relative costs of different technologies, and the amount of waste DOE actually intends to process through a vitrification plant. These changes suggest that earlier planning decisions need to be validated with updated information to ensure that the current approach is reasonable and appropriate. DOE's high-level waste project team also recognized that the DOE officials at Hanford had not performed a current, rigorous analysis of low-activity waste treatment options including the use of grout as an alternative to vitrification, and encouraged the Hanford site to update its analysis based on current waste treatment and disposal assumptions. Hanford officials responded by developing life-cycle cost estimates that compared the cost of alternate low-activity waste approaches. However, they did not reassess the decision to vitrify low-activity waste. DOE officials at Hanford told us they do not plan to reassess the decision to construct a low-activity vitrification facility because their compliance agreement with the state of Washington calls for vitrification of this waste.

In our previous work, we noted a similar lack of rigor in reevaluating DOE decisions as conditions change. For example, at three sites—Fernald, Ohio; Oak Ridge, Tennessee; and the Idaho National Laboratory—DOE was faced with a decision about whether to dispose of low-level waste on-site or to use off-site commercial disposal facilities. Between the time that DOE decided to develop on-site disposal facilities at these three sites and the time that construction actually began, conditions changed that affected the usefulness of earlier cost estimates. However, DOE officials at the sites made little effort to update and reevaluate the original cost comparisons to validate the on-site disposal decision.[33]

[33] U.S. General Accounting Office, *Nuclear Cleanup: DOE Should Reevaluate Waste Disposal Options Before Building New Facilities*, GAO-01-441 (Washington, D.C.: May 25, 2001).

This weakness cuts across the issues that the DOE teams are working on; no DOE team appears to be currently addressing it. However, DOE managers need to ensure that it receives proper consideration as these management improvement efforts proceed.

New Technology Is Incorporated Before It Is Sufficiently Mature

Our work on Department of Defense acquisitions has documented a set of "best practices" used by industry for integrating new technology into major projects. We reported in July 1999 that the maturity of a technology at the start of a project is an important determinant of success.[34] As technology develops from preconceptual design through preliminary design and testing, the maturity of the technology increases and the risks associated with incorporating that design into a project decrease. Waiting until technology is well-developed and tested before integrating it into a project will greatly increase the chances of meeting cost, schedule, and technical baselines. On the other hand, integrating technology that is not fully mature into a project greatly increases the risk of having cost increases and schedule delays. According to industry experts, correcting problems after a project has begun can cost 10 times as much as resolving technology problems beforehand.

DOE's project management guidance issued in October 2000 is consistent with these best practices. The guidance discusses technology development and sets out suggested steps to ensure that new technology is brought to a sufficient level of maturity at each decision point in a project. For example, during the conceptual design phase of a project, "proof of concept" testing should be performed before approval to proceed to the preliminary design phase. Furthermore, the guidance states that projects that attempt to concurrently develop the technology and design the facility proceed with ill-defined risks to all three baselines--cost, schedule, and technical.

[34] U.S. General Accounting Office, *Best Practices: Better Management of Technology Development Can Improve Weapon System Outcomes*, GAO/NSIAD-99-162 (Washington, D.C.: July 30, 1999).

Nevertheless, as we discussed earlier in this report, DOE sites continue to integrate immature technologies into their projects. For example, at Hanford, DOE is constructing a facility to separate high-level waste components, although integrated testing of the many steps in the separations process has not occurred and will not occur until after the facility is completed. DOE, trying to keep the project on schedule and within budget, has decided the risks associated with this approach are acceptable. However, there are many projects in which this approach created schedule delays and unexpected costs. The continued reliance on this approach in the face of so many past problems is a signal of an area that needs careful attention as DOE proceeds with its management reform efforts. At present, no DOE management team is addressing this issue.

Facility Construction Starts Before Design Is Sufficiently Developed

Finally, we have concerns about DOE's practice of launching into construction of complex, one-of-a-kind facilities well before their final design is sufficiently developed, again in an effort to save time and money. Both DOE guidance and external reviews stress the importance of adequate upfront planning before beginning project construction. DOE's project management guidance identifies a series of well-defined steps before construction begins and suggests that complex projects with treatment processes that have never before been combined into a facility do not lend themselves to being expedited. However, DOE guidance does not explicitly prohibit a fast-track –or concurrent design and construction-- approach to complex, one-of-a-kind projects, and DOE often follows this approach. For example, at the Hanford site, DOE is concurrently designing and constructing facilities for the largest, most complex environmental cleanup job in the United States. Problems are already surfacing. Only 24 months after the contract was awarded, the project was 10 months behind schedule dates, construction activities have outpaced design work causing inefficient work sequencing, and DOE has withheld performance fee from the design/construction contractor because of these problems.

DOE experienced similar problems in concurrent design and construction activities on other waste treatment facilities. Both the spent nuclear fuel project at Hanford and the waste separations facility at the Savannah River site encountered schedule delays and cost increases in part because the concurrent approach led to mistakes and rework, and required extra time and money to address the problems.[35] In its 2001 follow-up report on DOE project management, the National Research Council noted that inadequate pre-construction planning and definition of project scope lead to cost and schedule overruns on DOE's cleanup projects.[36] The Council reported that research studies suggest that inadequate project definition accounts for 50 percent of the cost increases for environmental remediation projects.

Again, no team is specifically examining the "fast-track" approach, yet it frequently contributed to past problems and DOE continues to use this approach.

Conclusions

DOE's efforts to improve its high-level waste cleanup program and to rein in the uncontrolled growth in project costs and schedules are important and necessary. The accelerated cleanup initiative represents at least the hope of treating and disposing of the waste in a more economical and timely way, although the actual savings are unknown at this time. Furthermore, specific components of this initiative face key legal and technical challenges. Much of the potential for success rests on DOE's continued ability to dispose of large quantities of waste with relatively low concentrations of radioactivity on-site by applying its incidental waste process. DOE's authority in this regard has been challenged in a lawsuit that is still pending. Much of the success also rests on DOE's ability to obtain successful technical performance from its as-yet unproven waste separation processes. Any technical problems with these processes will likely result in costly delays. At DOE's Hanford Site, we believe the potential for such problems warrants reconsidering the need for more thorough testing of the processes.

[35] For a discussion of the problems associated with the fast track design/build approach on these projects, see U.S. General Accounting Office, *Nuclear Waste: DOE's Hanford Spent Nuclear Fuel Storage Project—Cost, Schedule, and Management Issues*, GAO/RCED-99-267 (Washington, D.C.: Sept. 20, 1999) and *Nuclear Waste: Process to Remove Radioactive Waste From Savannah River Tanks Fails to Work*, GAO-RCED-99-69 (Washington, D.C.: Apr. 30, 1999).

[36] National Research Council, *Progress in Improving Project Management at the Department of Energy* (Washington, D.C.: Nov. 2001).

DOE's accelerated cleanup initiative should mark the beginning, not the end, of DOE's efforts to identify other opportunities to improve the program by accomplishing the work more quickly, more effectively, or at less cost. As DOE continues to pursue other management improvements, it should reassess certain aspects of its current management approach, including the quality of the analysis underlying key decisions, the adequacy of its approach to incorporating new technologies into projects, and the merits of a fast-track approach to designing and building complex nuclear facilities. Although the challenges are great, the opportunities for program improvements are even greater. Therefore, DOE must continue its efforts to clean up its high-level waste while demonstrating tangible, measurable program improvements.

Recommendations for Executive Action

To help ensure that DOE's accelerated cleanup initiative is effective and that cleanup of high-level waste proceeds in a timely and cost-effective manner, we recommend that the Secretary of the Department of Energy

- Reassess the potential risks, costs, and benefits of constructing a pilot-scale waste separations facility at the Hanford site to more fully test separations technologies before constructing a full-scale facility;

- Seek clarification from the Congress regarding DOE's authority for designating waste as incidental to reprocessing if the current challenge becomes an extended legal process, in order to help DOE determine what strategy it needs to move its initiative forward and realize potential savings;

- Ensure that DOE's high-level waste projects (1) include a current and rigorous analysis of the risks, costs, and benefits associated with the decisions being implemented, (2) incorporate new technologies consistent with best practices and DOE guidance so that risks and costs are more effectively managed, and (3) are carefully evaluated as to the appropriateness of using a fast-track approach to designing and constructing complex nuclear facilities, and that the potential risks and costs associated with this approach are explicitly identified and considered.

Agency Comments

We provided a draft of this report to the Department of Energy for its review and comment.
The full text of DOE's comments and our evaluation of them are included in appendix I.

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We conducted our review from July 2002 through May 2003, in accordance with generally accepted government auditing standards. Appendix II provides details on our scope and methodology.

As arranged with your office, unless you publicly announce its contents earlier, we plan no further distribution of this report until 30 days after the date of this letter. At that time, we will send copies to the Secretary of Energy. We will also make copies available to others on request. In addition, the report will be available at no charge on the GAO Web site at http://www.gao.gov. If you or your staff have any questions on this report, please call me at (202) 512-3841. Other staff contributing to this report are listed in appendix III.

Sincerely yours,

Robin M. Nazzaro
Director, Natural Resources and Environment

Appendix I: Comments from the Department of Energy

Appendix II: Scope and Methodology

To describe the components of DOE's high-level waste and the process involved in preparing the waste for permanent disposal, we analyzed information and documents provided by DOE officials and contractors at the four sites containing DOE high-level waste: Hanford, Washington; Idaho National Laboratory, Idaho; Savannah River, South Carolina; and West Valley, New York. We did not independently verify the accuracy of the information provided by each DOE site. From these same sites, we also obtained information on the types, age, and condition of the facilities used to store the high-level waste. To assist in evaluating technical aspects of high-level waste, we obtained assistance from our technical consultant, Dr. George Hinman. Dr. Hinman has a Doctor of Science degree in nuclear physics, is Professor Emeritus at the Washington State University, and has extensive experience in the nuclear energy field in industry, government, and academia.

To examine DOE's initiative for accelerating its high-level waste cleanup and the associated potential cost savings, we obtained and reviewed the Performance Management Plans for each of DOE's four high-level waste sites (Hanford, Savannah River, Idaho National Laboratory, and West Valley). We discussed these initiatives thoroughly with officials from each of the sites and obtained documentation discussing the proposed initiatives, as well as savings estimates. We reported all dollar estimates as provided by DOE in current dollars and did not adjust these figures to constant dollars. We did not verify the accuracy of cost information provided by DOE. We also reviewed guidance from the Office of Management and Budget circulars, especially circular A-94, on the type of analysis that federal agencies should use when developing benefit and cost estimates, and compared DOE's proposed savings estimates to that guidance. We analyzed savings estimate figures provided by DOE's Savannah River staff, discounting the dollars to provide an estimate in constant dollars.

To identify the legal challenges DOE faces, we obtained documentation relating to the current Natural Resources Defense Council (NRDC) lawsuit. We discussed the lawsuit separately with attorneys from the NRDC, as well as from DOE. We also discussed the waste-incidental-to-reprocessing process with staff at the NRC. We documented each site's incidental waste determinations, as well as historical information on the development of DOE Order 435.1. We also reviewed the appropriate statutes, related regulations and orders. To identify the technical challenges and issues that must be resolved to realize potential savings, we obtained documentation on the technical uncertainties and risks associated with the waste treatment approaches at the Hanford, Idaho National Laboratory, and Savannah River sites. Because waste separation is central to successful high-level waste treatment and disposal, we documented the status of each site's approach. We identified the major technical concerns, uncertainties, and risks associated with the waste separations approaches and discussed them with DOE and contractor officials at each site. We also visited the Savannah River Technology Center to review the progress and results of laboratory tests conducted to develop the Savannah River and Hanford sites' waste separations technology. With the assistance of our technical consultant, we contacted a variety of independent experts in industry and academia to obtain their views on the risks associated with these technologies.

To determine additional opportunities for reducing high-level waste program costs, we reviewed DOE waste acceptance policies and requirements, planning documents, position papers, and internal memos. We discussed the opportunities with DOE officials, contractors, and laboratory officials primarily at the Hanford, Idaho National Laboratory, and Savannah River sites. We compared the cost savings concepts with those presented in performance management plans at each site to document that they represented additional opportunities. We also relied on the expertise of our technical consultant to help assess the technical viability of DOE's proposals. To determine opportunities to improve the management of the program, we reviewed DOE's Top-to-Bottom report and we discussed management reform proposals with officials at DOE headquarters. We also obtained documentation on DOE's project review teams. We reviewed prior reports from GAO, DOE's IG and the National Research Council to identify recurring weaknesses in DOE management of its cleanup program, and we developed current examples of those weaknesses from our work at the high-level waste sites and meetings with DOE officials. We also compared management weaknesses we identified to DOE's current reform efforts to determine the extent to which the weaknesses were being addressed and to identify areas needing continued attention.

We conducted our review from July 2002 through May 2003 in accordance with generally accepted government auditing standards.

Appendix III: GAO Contact and Staff Acknowledgements

GAO Contacts

William R. Swick (206) 287-4800

Staff Acknowledgements

In addition to those named above, Carole Blackwell, Robert Crystal, Doreen Feldman, Chris Hatscher, Gary Jones, Nancy Kintner-Meyer, Avani Locke, Mehrzad Nadji, Tom Perry, and Stan Stenersen made key contributions to this report.

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